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**U.S. PATENT APPLICATION**

**FOR**

**COMPOSITE DISK CLAMP ASSEMBLY FOR  
REDUCED CURVATURE AND COST**

**INVENTOR(S):**  
Norbert A. Feliss  
Donald R. Gillis  
Reinhard F. Wolter

**ASSIGNEE:**      **HITACHI GLOBAL STORAGE TECHNOLOGIES**

SILICON VALLEY IP GROUP, PC  
P.O. Box 721120  
SAN JOSE, CA 95172

# COMPOSITE DISK CLAMP ASSEMBLY FOR REDUCED CURVATURE AND COST

## FIELD OF THE INVENTION

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The present invention relates to disk drive components, and more particularly, this invention relates to a composite disk clamp that provides high rigidity and integral material matching at the disk-clamp interface.

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## BACKGROUND OF THE INVENTION

- A typical disk drive storage system includes one or more magnetic disks which are mounted for co-rotation on a hub or spindle. A typical disk drive also includes a transducer supported by a hydrodynamic bearing which flies above each magnetic disk.
- 15     The transducer and the hydrodynamic bearing are sometimes collectively referred to as a data head or a product head. A drive controller is conventionally used for controlling the disk drive based on commands received from a host system. The drive controller controls the disk drive to retrieve information from the magnetic disks and to store information on the magnetic disks. An electromechanical actuator operates within a negative feedback,
- 20     closed-loop servo system to move the data head radially or linearly over the disk surface for track seek operations and holds the transducer directly above a desired track or cylinder on the disk surface for track following operations.

Typically the magnetic disks **2** also comprise servo sectors **18** which are recorded at a regular interval and interleaved with the data sectors **12**, as shown in FIG. 1. A servo sector, as shown in FIG. 2, typically comprises a preamble **20** and sync mark **22** for synchronizing to the servo sector; a servo data field **24** comprising coarse position information, such as a Gray coded track address, used to determine the radial location of the head with respect to the plurality of tracks; and a plurality of servo bursts **26** recorded at precise intervals and offsets from the track centerlines which provide fine head position information. When writing or reading data, a servo controller performs a "seek" operation to position the head over a desired track; as the head traverses radially over the recording surface, the Gray coded track addresses in the servo data field **24** provide coarse position information for the head with respect to the current and target track.

When the head reaches the target track, the servo controller performs a tracking operation wherein the servo bursts **26** provide fine position information used to maintain the head over the centerline of the track as the digital data is being written to or read from the recording surface.

To ensure that the head remains properly aligned with the data tracks, the disks must be securely attached to the spindle. Current practice is to separate the disks in the stack with spacer rings, and position a spacer ring on top of the disk/spacer stack. Then a top ring, called a clamp, with several apertures is placed over the top spacer ring. The disks are bolted to the spindle via bolts extending through the apertures in the top clamp. Great pressure must be exerted by the bolts on the top clamp in order to prevent slippage of the disks in the event that the drive is bumped or uneven thermal expansion that breaks

the frictional coupling, because once the disks slip, the drive loses its servo and the data is lost.

Disks are typically formed from aluminum or glass. Aluminum is more easily deformed, so any external stress can cause deformations to the disk. Glass, too, will 5 deform under uneven stress patterns.

A major drawback of the current practice is that when the bolts are tightened, the top clamp and spacer become deformed due to the uneven pressures exerted by the individual bolts. The deformation translates out to the disk, creating an uneven "wavy" disk surface, which is most prominent at the inner diameter of the disk. Any unevenness 10 (waviness) on the disk surface compounds the tendency to lose the servo, especially near the inner diameter zone closest to the spacer ring.

Further, it has been found that stresses induced on the top disk in the stack transfer down and propagate into some or all of the remaining disks in the stack. Thus, it would be desirable to reduce uneven stresses at the top disk so that the remaining disks 15 remain flat.

Another issue encountered in the prior art is the high cost of assembling the drives. Each spacer must be placed in the drive and then the top clamp added and bolted down. This process is time consuming. To reduce assembly costs, it would be desirable to couple the top clamp and top spacer ring together so that they can be placed in the drive 20 at the same time. This would save a processing step in that only one piece (top clamp-spacer composite) need be handled instead of two parts (top clamp and spacer ring individually).

The cost savings obtainable by using a composite structure would be increased in new high capacity drives which require only a few disks as opposed to several. For example, in a drive with five disks, five parts must be handled: the top clamp-spacer composite and four more spacer rings. In a drive with only two disks, only two parts are 5 handled: the top clamp-spacer composite and one spacer.

Additional cost savings would be realized during manufacture of the top clamp and top spacer ring themselves, as it would no longer be necessary to machine two surfaces in such a way to match flatness.

**SUMMARY OF THE INVENTION**

A composite ring for coupling a disk to a spindle includes an upper layer

5     constructed of a material having a hardness at least as hard or harder than the primary material of the disk. The hardness of a material measures the vertical distance through which an indenter (generally a cone with a rounded end but sometimes a sphere) moves during an indentation process). The hardness number is somewhat influenced by the Young's modulus of the material in question. The composite ring being of slightly

10    higher hardness than the disk would allow its asperities to penetrate the surface layer of the disk to provide a large adhesion between the two surfaces, i.e. the surface of the composite ring together with the surface of the disk. A lower layer is fixedly coupled to the upper layer and constructed of a material having similar material properties to that of the disk, the properties being selected from a group consisting of a coefficient of thermal

15    expansion and Young's modulus.

Preferably, the upper layer has a hardness of between about 20 and about 250 kg/mm<sup>2</sup>. Also preferably, the upper layer is constructed of a material having a Young's modulus greater than that of the primary material of the disk. An illustrative modulus range of the upper layer is between about 60 and about 300 GPa. The upper layer can be

20    constructed of, for example, chrome, titanium, nickel, stainless steel and composites and alloys thereof.

In another embodiment, the lower layer has a thermal expansion between about 1 and 25 ( $10^{-6}/C$ ) The lower layer can be constructed of various materials, including

aluminum and glass. Preferably, a ratio of a modulus of the upper layer to a modulus of the lower layer is between about 1 and 5.

A middle layer may be fixedly coupled between the upper and lower layers. The various layers can be coupled together via mechanical bonding, an adhesive, and/or via  
5 bonding at the molecular level.

Thus, the composite structure described herein reduces the parts count and the cost associated with an individual clamp and spacer ring. The composite material choices also allow better thermal expansion, stiffness and Young's modulus which is mated and matched substantially perfectly to the top disk of the stack. Under torquing requirements  
10 the stress is spread out evenly over the top disk so as to minimize tangential and radial curvature effects.

**BRIEF DESCRIPTION OF THE DRAWINGS**

For a fuller understanding of the nature and advantages of the present invention, as  
5 well as the preferred mode of use, reference should be made to the following detailed  
description read in conjunction with the accompanying drawings.

FIG. 1 shows a typical format for of a disk surface comprising a plurality of  
radially spaced, concentric data tracks partitioned into a number of data sectors and  
embedded servo sectors for positioning the heads over the disk surfaces while seeking  
10 and tracking.

FIG. 2 shows a typical format of an embedded servo sector.

FIG. 3 is a schematic and simplified vertical sectional view of a rigid magnetic  
disk drive unit embodying the present invention.

FIG. 4 is a top plan view of the structure shown in FIG. 3.

15 FIG. 5 is a perspective view of a composite spacer according to one embodiment.

FIG. 6A is an exaggerated cross-sectional view of a composite ring with upper  
and lower layers coupled together via a series of ridges and troughs.

FIG. 6B is an exaggerated cross-sectional view of a composite ring with upper  
and lower layers coupled together via a series of dovetail protrusions and receiving areas.

20 FIG. 6C is an exaggerated cross-sectional view of a composite ring with upper  
and lower layers coupled together via a series of bulbous protrusions and receiving areas.

FIG. 7 is a side view of the first layer of FIG. 6A taken along lines 7-7 of FIG.  
6A.

FIG. 8 is a cross-sectional view of a clamp/spacer ring assembly according to one embodiment.

FIG. 9 is a cross-sectional view of a clamp/spacer ring assembly according to another embodiment.

5 FIG. 10 is a cross-sectional view of a clamp/spacer ring assembly according to yet another embodiment.

**BEST MODE FOR CARRYING OUT THE INVENTION**

The following description is the best embodiment presently contemplated for  
5 carrying out the present invention. This description is made for the purpose of illustrating  
the general principles of the present invention and is not meant to limit the inventive  
concepts claimed herein.

Referring now to the drawings wherein like reference numerals designate like or  
similar parts throughout the several views there is illustrated in FIG. 3 a cross-sectional  
10 diagram of parts of a data storage disk drive system 30 including a rigid magnetic disk  
drive unit generally designated as 32 and a control unit generally designated as 34. While  
a magnetic disk drive unit is illustrated, it should be understood that other mechanically  
moving memory configurations may be used. Unit 32 is illustrated in simplified form  
sufficient for an understanding of the present invention because the utility of the present  
15 invention is not limited to the details of a particular drive unit construction. After data  
storage disk drive system 30 is completely assembled, servo information used to write  
and read data is written using the disk drive system 30.

Referring now to FIGS. 3 and 4 of the drawing, disk drive unit 32 includes a stack  
36 of disks 38 having at least one magnetic surface 40. The disks 38 are mounted in  
20 parallel for simultaneous rotation on and by an integrated spindle and motor assembly 46.  
The disks 38 are separated by spacers 33 and are coupled to the spindle at the top by a  
composite clamp ring 70 which is pressed onto the stack of disks 38 by bolts 35.

Data information on each disk **38** are read and/or written to by a corresponding transducer head **48** movable across the disk surface **40**. In a disk drive using a dedicated or hybrid servo, one of the disk surfaces **40'** stores servo information used to locate information and data on the other disk surfaces **40**.

5 Transducer heads **48** are mounted on flexure springs **50** carried by arms **52** ganged together for simultaneous pivotal movement about a support spindle **54**. One of the arms **52** includes an extension **56** driven in a pivotal motion by a head drive motor **58**. Although several drive arrangements are commonly used, the motor **58** can include a voice coil motor **60** cooperating with a magnet and core assembly (not seen) operatively  
10 controlled for moving the transducer heads **48** in synchronism in a radial direction in order to position the heads in registration with data information tracks or data cylinders **62** to be followed and access particular data sectors **64**. Although a rotary actuator is shown, it should be understood that a disk drive with a linear actuator can be used. Data storage disk drive system **30** is a modular unit including a housing **66**. The various  
15 components of the disk drive system **30** are controlled in operation by signals generated by control unit **34** such as motor control signals on line **46A** and position control signals on line **58A**.

Numerous data information tracks **62** are arrayed in a concentric pattern in the magnetic medium of each disk surface **40** of data disks **38**. A data cylinder includes a set  
20 of corresponding data information tracks **62** for the data surfaces **40** in the data storage disk drive system **30**. Data information tracks **62** include a plurality of segments or data sectors **64** each for containing a predefined size of individual groups of data records which are saved for later retrieval and updates. The data information tracks **62** are

disposed at predetermined positions relative to servo information, such as a servo reference index. In FIG. 4 one sector 64 is illustrated as SECTOR O with a fixed index or mark INDEX for properly locating the first data sector. The location of each next sector 64 is identified by a sector identification (SID) pulse read by transducer heads 48 from surfaces 40, 40'.

FIG. 5 illustrates a composite top clamp ring 70 according to one embodiment. The composite ring 70 includes a stiff annular upper layer 72 that provides rigidity to the clamping structure 70 by providing a more even distribution of stresses on the disks below from the clamping bolts coupled to the composite ring 70 through the apertures 76, which in turn reduces deformation of the disk(s). An annular lower layer 74 is fixedly coupled to the upper layer 72. The lower layer 74 may be of secondary stiffness and is preferably made of a material similar to the disk, e.g., aluminum or ceramic. The highly rigid upper layer 72 of the composite ring 70 reduces deformation caused by the clamping stresses, yet the composite ring 70 provides high mechanical stability due to integral material matching for the clamping interface. The material-matching at the ring-disk interface allows the lower layer 74 and the disk to expand and contract together under temperature variations. (Using a hard material for the lower layer 74 would cause the bottom layer to expand out of phase with the disk.)

The upper layer 72 of the composite ring is preferably made of a material with a high hardness and high modulus so that it is less susceptible to bending and/or cracking under the stress of the clamping forces. Preferably, the upper layer 72 has a material hardness and/or modulus that is at least as hard as the disk itself. Thus, if an aluminum disk is used in the drive, the stiffening layer should have a hardness at least about the

same as the aluminum material used to form the disk. Illustrative materials from which the upper layer **72** can be formed are nickel, titanium, chrome, stainless steel, materials treated (e.g., doped) for stiffness and hardness, silicon nitride, aluminum nitride, alloys, composites, etc.

5       The lower layer **74** is preferably constructed of a material which is of a similar or about the same coefficient of thermal expansion as that of the primary material of the disk, i.e., disk substrate of glass, aluminum, etc. The thermal conductivity parameter shown in Table 1 (below) is important but to a lesser extent than the coefficient of thermal expansion and the Young's modulus of the material. The thermal conductivity  
10      should be similar to the disk since heat from the motor does not build up in the lower layer **74** but can transmit to the disk uniformly.

The following table lists several materials from which the composite ring **70** can be constructed, and their properties. Note that the modulus is a measure of the load a material can handle before it starts to deform.

**Table 1**

	<b>Material</b>	<b>Hardness (kg/mm<sup>2</sup>)</b>	<b>Modulus (GPa)</b>	<b>Thermal</b>	<b>Coefficient of</b>
				<b>Conductivity (W/m-K)</b>	<b>Thermal Expansion (10<sup>-6</sup>/C)</b>
5	Aluminum	27	70	221	25
	Chrome	125	26	14	6
	Titanium	65	110	2	8.5
	Nickel	210	200	60	13
10	Glass	185	63	1	4
	Stainless Steel	160	205	16	12

An illustrative range of materials usable in the composite ring 70 have a hardness of about 20 to about 250 kg/mm<sup>2</sup>, a modulus of about 60 to about 300 GPa and a thermal expansion between 1 and 25 (10<sup>-6</sup>/C). Note that glass and aluminum have about the similar Young's modulus, but the aluminum has about 6 times the coefficient of thermal expansion as glass. Therefore, an aluminum spacer is preferred for use with aluminum disks, while a ceramic spacer is preferred for use with glass disks.

The following table illustrates exemplary Young's modulus ratios for the upper and lower layers of the composite ring 70. The modulus ratio is important as a measure of how well the composite ring 70 will provide the desired properties.

**Table 2**

<b>Material Combination</b>	<b>Modulus Ratio of Two Materials: first + second layer</b>
5    Stainless Steel Clamp with Aluminum spacer	205/70 = 3.0
Stainless Steel Clamp with Glass spacer	205/63 = 3.3
Titanium Clamp with Aluminum spacer	110/70 = 1.6
Titanium Clamp with Glass spacer	110/63 = 1.8
10      A preferred modulus ratio range can be shown by the following: 1.0 < Modulus Ratio < 5.0. However, this range may not be all inclusive and would allow some combinations outside of this range, especially using nonmetallic disks and clamps, i.e. plastic and silicon disks with plastic and silicon lower layers 74. When glass disks are used, an illustrative modulus ratio of about 3.3 is provided by a stainless steel upper layer	
15      72 and a ceramic lower layer.	
	A middle layer of the composite ring, positioned between the upper and lower layers 72, 74, can be added to achieve the desired overall modulus ratio. The middle layer can be constructed of another material such as one or more of stainless steel, chrome, nickel, etc. and composites and alloys thereof.
20      The layers of the composite ring 70 can be coupled together using any suitable process. Several techniques to perform such bonding are described below. Three particular techniques include mechanical bonding, adhesive chemical bonding, and bonding at the molecular level.	
	Mechanical bonding of the layers can be achieved by protrusions and corresponding receiving areas such as ridges/textured lines and coincident troughs. The

mechanical coupling encourages the various layers to expand and contract together, thereby maintaining the proper alignment.

FIG. 6A is an exaggerated view of the composite ring 70 with the upper and lower layers 72, 74 coupled together via a series of ridges 82 and troughs 84. FIG. 7 shows the 5 ridge structure on the bottom of the upper layer 72 which mates with a trough structure on the lower layer 74 to create the composite ring. The ridges 82 mate into the troughs 84, providing mechanical bonding and strength between the layers. With this type of mating for the composite ring 70, high structural integrity and superior bonding is maintained for a system that is exposed to the high stress of clamping a multi-disk pack.

10 Other variations to create the mechanical coupling can include random or nonrandom fingerlike perturbations and recesses, teeth (see FIG. 9), etc. To enhance the coupling, "dovetail" protrusions, bulbous protrusions, etc. can be used to form semi-permanent or permanent coupling. Note FIGS. 6B and 6C.

Chemical bonding can also be used individually, or in combination with 15 protrusions/receiving portions as described in the immediately preceding paragraphs. Adhesives such as silicon-based adhesives can be used to create the chemical bond. In a similar manner, bonding at the molecular level can be achieved by sintering, welding, ultrasonic welding, etc.

Because the two layers 72, 74 are coupled together, a processing step during drive 20 assembly is saved in that only one piece (clamp-spacer composite) need be handled instead of two parts (clamp and spacer). Additional cost savings are realized during manufacture of the annular layers 72, 74 themselves, as it is longer necessary to machine two surfaces to obtain a hardness match.

A clamp/spacer ring assembly according to another embodiment is constructed at least in part of plastic. Such a ring assembly 90, particularly suitable for use in a drive having disks themselves constructed at least in part of a plastic material, is shown in FIG. 8. The ring assembly 90 according to one embodiment includes a stiff annular clamp 92, 5 followed by an annular plastic spacer ring 94. The clamp 92 is preferably constructed of materials described above with respect to the first layer of the composite ring. The spacer ring 94 is preferably constructed of any plastic material having properties similar to that of the plastic in the disks, and may be formed or molded as a single layer, a composite structure, etc. Illustrative plastic materials include polyolefins, polyethylenes, 10 polycarbonates, polystyrenes, polyvinyl chlorides, polymers, resins, etc. In the embodiment shown in FIG. 8, the spacer ring 94 has glass beads 96 (or other material strengthening elements) of any shape embedded into the plastic matrix in a non-uniform manner. Preferably, the material strengthening elements are harder than the material from which the spacer ring 94 is constructed. This allows a gradient of density from high to 15 low (high closest to the clamp 92) which will allow a gradient of thermal expansion to be made more uniform from the stiff clamp 92 to the lower portion of the plastic spacer ring 94. Without this gradient the clamp 92/spacer ring 94 combination would suffer from thermal expansion properties as well as modulus problems. The plastic lower layer closest to the clamp 92 would have a high density of materials, allowing for a thermal 20 expansion and modulus closest to the clamp 92. The portion of the plastic ring closest to the plastic disk would then have material properties very similar to that of the plastic disk being clamped. Preferably, some type of mechanical mating (e.g., see FIGS. 9 and 10) is

implemented to integrally couple the layers to prevent slipping of the layers, particularly where dissimilar materials are used.

Another way to obtain a non-uniform plastic structure is with teeth **102**, as shown in FIG. 9. The teeth **102** are preferably extensions from the clamp **92** which extend into the plastic matrix. The teeth **102** may be annularly aligned, segmented, randomly placed, etc. This will increase the density and modulus of the plastic structure and will give it similar material properties as explained in the previous paragraph. Note also that the teeth **102** and ridges **104** may also extend from the plastic ring **94** into the clamp **92**.

Yet another way to obtain a non-uniform plastic structure is with a ridge/trough **104, 106** combination, as shown in FIG 10. The teeth **104** are preferably extensions from the clamp **92** which extend into the plastic matrix. The ridges **104** may be annularly aligned, segmented, randomly placed, etc. This will increase the density and modulus of the plastic structure and will give it similar material properties as explained in the previous paragraphs. Note also that the ridges **104** may also extend from the plastic ring **94** into the clamp **92**.

The clamp **92** and plastic spacer ring **94** of the ring assemblies shown in FIGS. 8-10 can be installed individually in the disk drive. The mechanical coupling causes the layers to expand and contract together in a uniform fashion, thereby preventing the disk from going off-center. Alternatively, the clamp **92** and plastic spacer ring **94** can be fixedly coupled together to form a composite structure similar to that described above with respect to FIG. 5.

Thus, the composite structure described herein will reduce the parts count and the cost associated with an individual clamp **92** and spacer ring **94**. The composite material

choices will also allow better thermal expansion, stiffness and modulus which is mated and matched perfectly to the top disk of the stack. Under torquing requirements the stress is spread out evenly over the top disk so as to minimize tangential and radial curvature effects.

5        Composite structures that have a blend of coupling morphologies are also to be considered as a composite structure that are mechanically bonded to one another. The set of mechanical couplings indicated in the individual FIGS. 6A, 6B and 6C can be blended into one as a combination, i.e. A+B, A+C, B+C. Also, for the plastic clamp/ring structure shown in FIGS. 9 and 10, these can also be combined, i.e. 9+10.

10      While various embodiments have been described above, it should be understood that they have been presented by way of example only, and not limitation. Thus, the breadth and scope of a preferred embodiment should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.